New Stuyahok, Alaska Wind Resource Report

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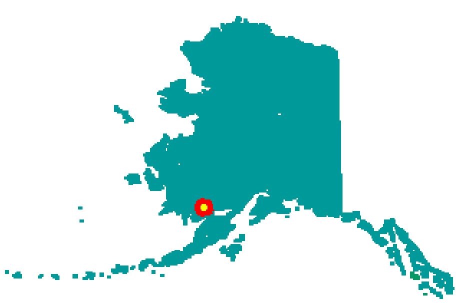
Photo © Doug Vaught



Summary Information

New Stuyahok has fair to good potential for wind power development, provided a slightly better location for wind turbines is found than the meteorological tower test site. The test site appeared to be adversely affected by the presence of trees nearby. When the new airfield opens and the old one abandoned, the old runway would be an ideal location for wind turbines: it is higher and more open than the met tower test site, and turbine foundations would be easier to construct.

Data Synopsis

Wind power class	Class 4 – Good
Wind speed annual average (30 meters)	5.46 m/s
Maximum wind speed measured	33.6 m/s, November 2004
Mean wind power density (50 meters)	414 W/m^2 (calculated*)
Mean wind power density (30 meters)	232 W/m^2 (measured)
Weibull distribution parameters	k = 1.76, c = 6.29 m/s
Roughness Class	4.39 m (suburban)
Power law exponent	0.382 (high wind shear)
Turbulence Intensity	0.151 (moderate to high)
Data start date	October 10, 2003
Data end date	July 7, 2005

*Wind power density at 50 meters likely an overestimate due to high shear measured

Community Profile

Current Population:	472 (2005 State Demographer est.)
Pronunciation/Other Names:	(STEW-yuh-hawk)
Incorporation Type:	2nd Class City
Borough Located In:	Unorganized
School District:	Southwest Region Schools
Regional Native Corporation:	Bristol Bay Native Corporation

Location:

New Stuyahok is located on the Nushagak River, about 12 miles upriver from Ekwok and 52 miles northeast of Dillingham. The village has been constructed at two elevations -- one 25 feet above river level, and one about 40 feet above river level. It lies at approximately 59.452780° North Latitude and -157.311940° West Longitude. (Sec. 29, T008S, R047W, Seward Meridian.) New Stuyahok is located in the Bristol Bay Recording District. The area encompasses 32.6 sq. miles of land and 2.0 sq. miles of water.

History:

The present location is the third site that villagers can remember. The village moved downriver to the Mulchatna area from the "Old Village" in 1918. During the 1920s and 30s, the village was engaged in herding reindeer for the U.S. government. However, by 1942 the herd had dwindled to nothing; the village had been subjected to flooding; and the site was too far inland even to receive barge service. So in 1942, the village moved downriver again to its present location. Stuyahok appropriately means "going downriver place." The first school was built in 1961. A post office was also established during that year. An airstrip was built soon thereafter, and the 1960s saw a 40% increase in the village population. The City was incorporated in 1972.

Culture:

New Stuyahok is a southern Yup'ik Eskimo village with Russian Orthodox influences. Residents practice a fishing and subsistence lifestyle.

Economy:
The primary economic base in New Stuyahok is the salmon fishery; forty-three residents hold commercial fishing permits. Many trap as well. The entire community relies upon subsistence foods. Subsistence items are often traded between communities. Salmon, moose, caribou, rabbit, ptarmigan, duck and geese are the primary sources of meat.

Facilities:
Water is derived from a well and is treated. A new well is under development. The majority of the community (94 homes), facilities and the school are connected to a piped water and sewer system installed in 1971 and have complete plumbing. Some residents use individual wells and septic tanks; six homes are without complete plumbing. A Master Plan has been funded.

Transportation:
Air transport is most frequently used to reach the community. Regular and charter flights are available from Dillingham. The State-owned gravel airstrip is 1,800' long by 50' wide and lighted. It is located on a hilltop; windy conditions often preclude landing. The community has requested funds for construction of a crosswind landing strip. There are no docking facilities. Goods are lightered on a regular basis during the summer. Skiffs, ATVs and snowmachines are prevalent forms of local transportation.

Climate:
New Stuyahok is located in a climatic transition zone. The primary influence is maritime, although a continental climate affects the weather. Average summer temperatures range from 37 to 66; winter temperatures average 4 to 30. Annual precipitation ranges from 20 to 35 inches. Fog and low clouds are common during the summer; strong winds often preclude access during the winter. The River is ice-free from June through mid-November.

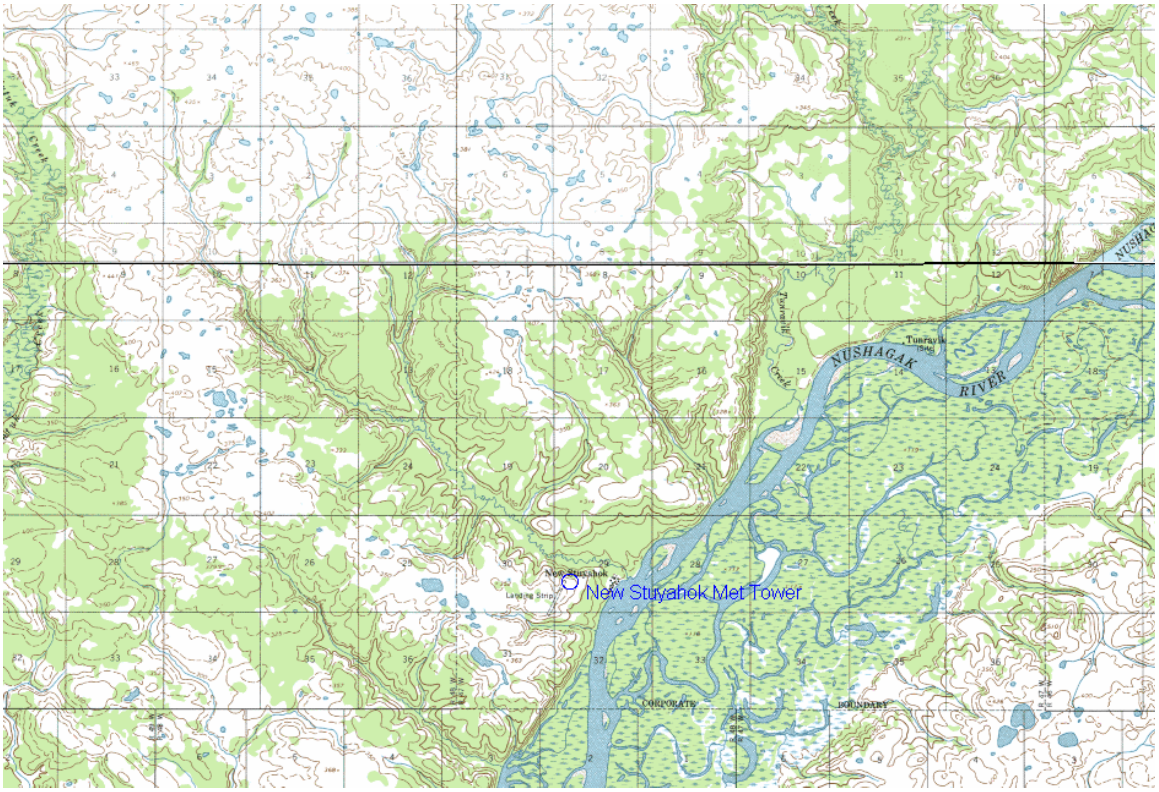
(Above information from State of Alaska Department of Commerce, Community and Economic Development website, www.dced.state.ak.us)

Tower Sensor Information

Channel	Sensor type	Height	Multiplier	Offset	Orientation
1	NRG #40 anemometer	30 m	0.765	0.35	north
2	NRG #40 anemometer	20 m	0.765	0.35	north
7	NRG #200P wind vane	30 m	0.351	090	west
9	NRG #110S Temp C	2 m	0.136	-86.383	N/A

Site Information and Location

Site number	0064
Site Description	New Stuyahok - AVEC
Latitude/longitude	N 59° 27.115’; W 157° 19.427’
Site elevation	125 meters
Datalogger type	NRG Symphonie
Tower type	NRG 30-meter tall tower, 152 mm (6-in) diameter


New Stuyahok Met Tower
NUSHAGAK
RIVER
CORPORATE
BOUNDARY
Landing Strip

Data Quality Control

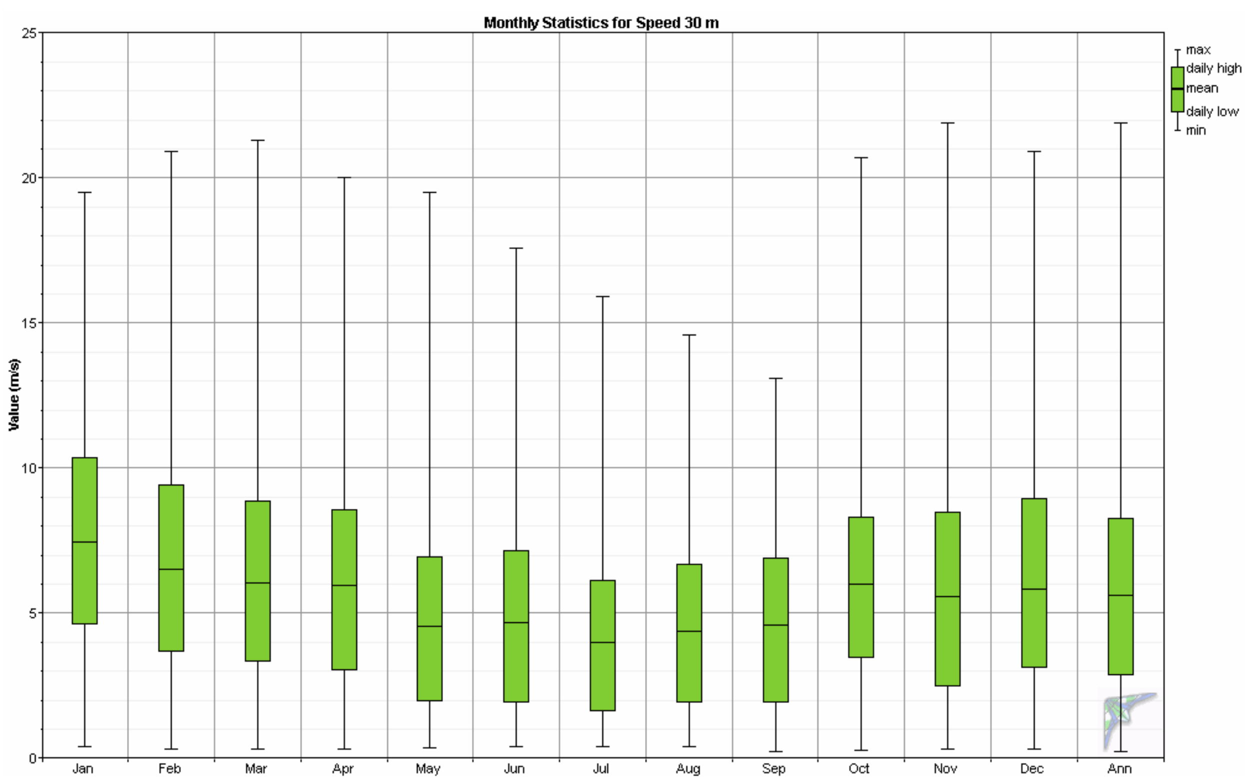
Data was filtered to remove presumed icing events that yield false zero wind speed data. Data that met the following criteria were filtered: wind speed < 1 m/s, wind speed standard deviation = 0, and temperature < 2 °C. Note that wind speed data recovery during the months of June, July and August was 100%, but during the winter months of November through March larger amounts data was filtered, with December being the most ice prone as far as data loss is concerned. Temperature data recovery was 100 percent, indicating full functioning of the temperature sensor. Data was synthesized to replace data removed due to icing events; the synthesized data set is used in this report.

		30 m anemometer		20 m anemometer		Wind vane		Temperature	
Year	Month	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)	Records	Recovery Rate (%)
2003	Oct	3,021	99.9	3,020	99.9	2,761	91.3	3,024	100
2003	Nov	4,274	98.9	4,202	97.3	3,871	89.6	4,320	100
2003	Dec	4,383	98.2	4,331	97.0	4,088	91.6	4,464	100
2004	Jan	4,190	93.9	4,189	93.8	4,456	99.8	4,464	100
2004	Feb	3,825	91.6	4,040	96.7	3,609	86.4	4,176	100
2004	Mar	4,338	97.2	4,330	97.0	4,303	96.4	4,464	100
2004	Apr	4,280	99.1	4,278	99.0	4,272	98.9	4,320	100
2004	May	4,458	99.9	4,457	99.8	4,456	99.8	4,464	100
2004	Jun	4,320	100	4,320	100	4,320	100	4,320	100
2004	Jul	4,464	100	4,464	100	4,464	100	4,464	100
2004	Aug	4,464	100	4,464	100	4,464	100	4,464	100
2004	Sep	4,286	99.2	4,275	99.0	4,274	98.9	4,320	100
2004	Oct	4,346	97.4	4,347	97.4	4,343	97.3	4,464	100
2004	Nov	3,868	89.5	3,906	90.4	3,111	72.0	4,320	100
2004	Dec	3,478	77.9	3,630	81.3	2,797	62.7	4,464	100
2005	Jan	4,102	91.9	4,081	91.4	4,201	94.1	4,464	100
2005	Feb	3,894	96.6	3,913	97.0	3,894	96.6	4,032	100
2005	Mar	4,205	94.2	4,226	94.7	4,200	94.1	4,464	100
2005	Apr	4,195	97.1	4,256	98.5	4,196	97.1	4,320	100
2005	May	4,464	100	4,464	100	4,464	100	4,464	100
2005	Jun	4,320	100	4,320	100	4,320	100	4,320	100
2005	Jul	912	100	912	100	912	100	912	100
All data		88,087	96.3	88,425	96.7	85,776	93.8	91,488	100

Measured Wind Speeds

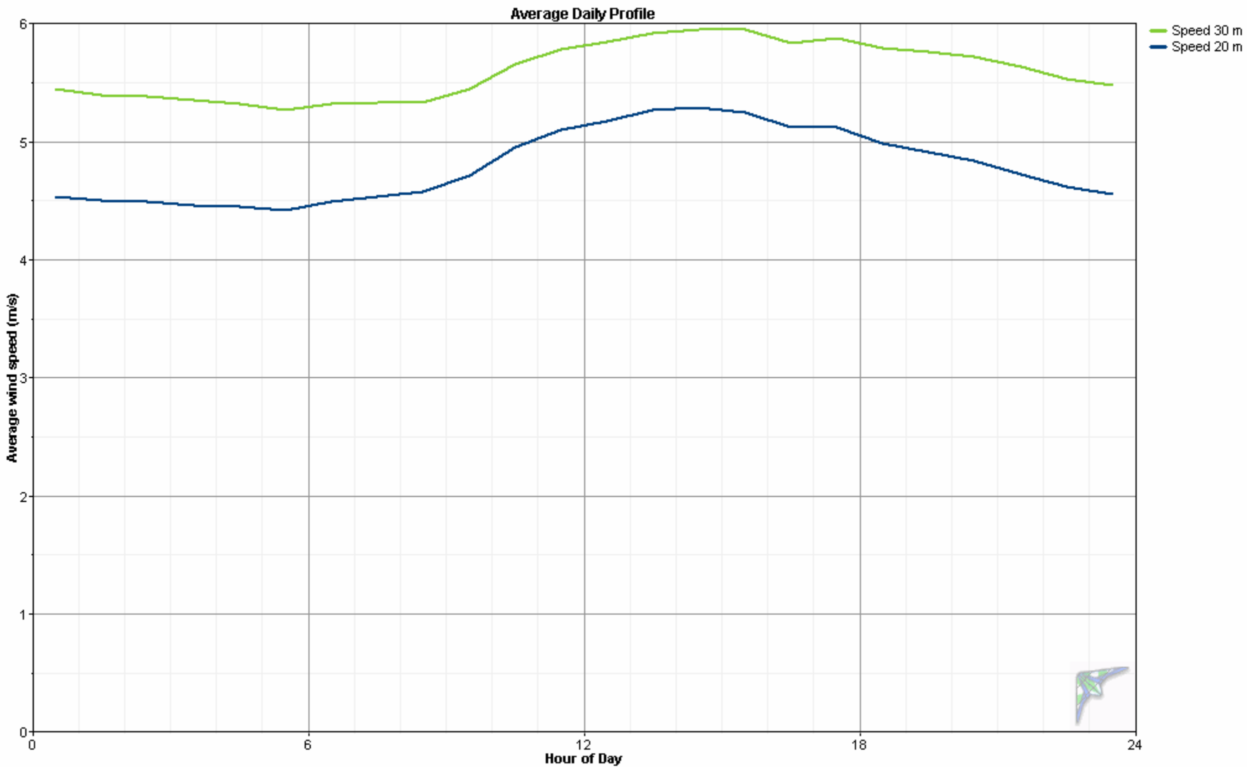
The 30 meter anemometer wind speed average for the reporting period is 5.46 m/s and the 20 meter anemometer wind speed average is 4.67 m/s.

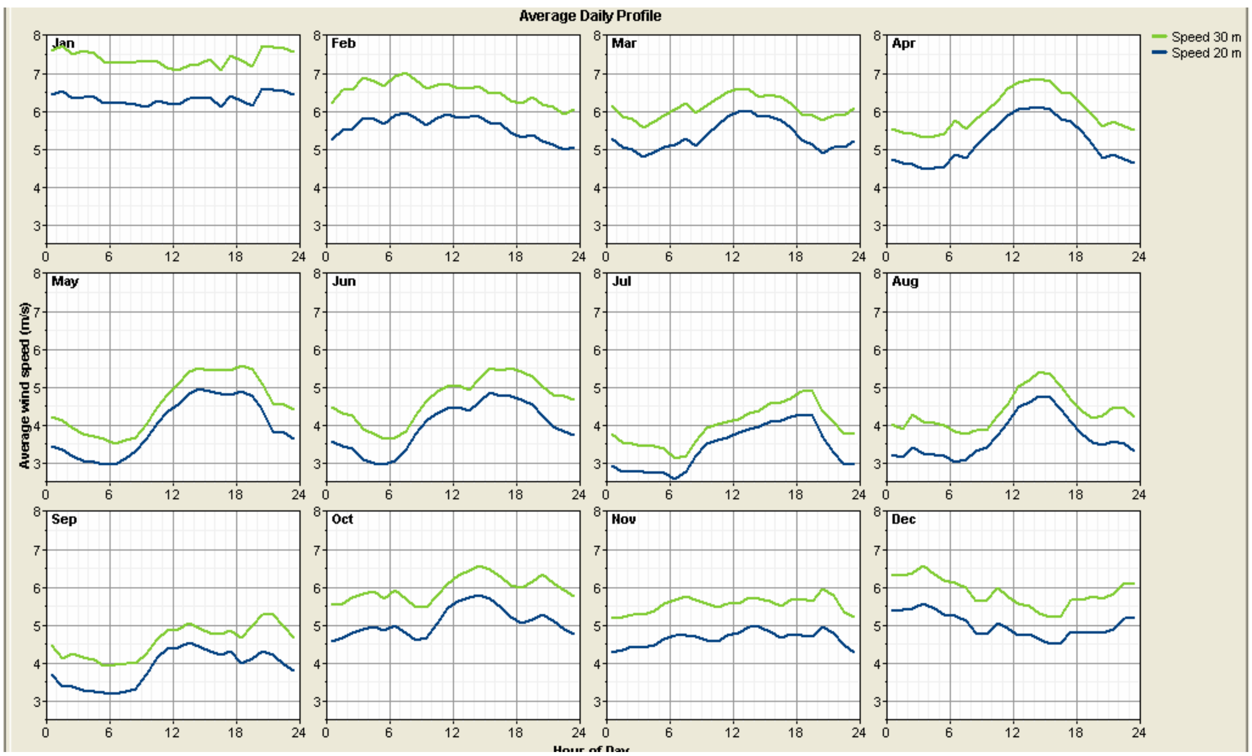
	30 m anemometer					20 m anemometer		
Month	Mean (m/s)	Max (m/s)	SD (m/s)	Weibull k	Weibull c (m/s)	Mean (m/s)	Max (m/s)	Std. Dev. (m/s)
Jan	7.44	19.5	3.10	2.54	8.36	6.43	16.8	2.81
Feb	6.52	20.9	3.58	1.90	7.35	5.59	17.6	3.12
Mar	6.06	21.3	3.34	1.88	6.81	5.31	18.1	2.94
Apr	5.97	20.0	3.51	1.76	6.71	5.19	17.3	3.08
May	4.56	19.5	3.08	1.52	5.07	3.95	15.9	2.59
Jun	4.68	17.6	2.94	1.63	5.23	3.98	14.4	2.44
Jul	3.98	15.9	2.22	1.89	4.49	3.40	12.9	1.92
Aug	4.38	14.6	2.49	1.84	4.93	3.68	12.6	2.16
Sep	4.58	13.1	2.76	1.68	5.12	3.87	11.5	2.51
Oct	5.99	20.7	2.98	2.08	6.74	5.11	17.0	2.64
Nov	5.58	21.9	3.09	1.87	6.29	4.69	18.7	2.74
Dec	5.85	20.9	3.31	1.83	6.58	4.99	19.0	2.98
All data	**5.46**	21.9	3.26	1.77	6.29	**4.67**	19.0	2.87



Daily Wind Profile

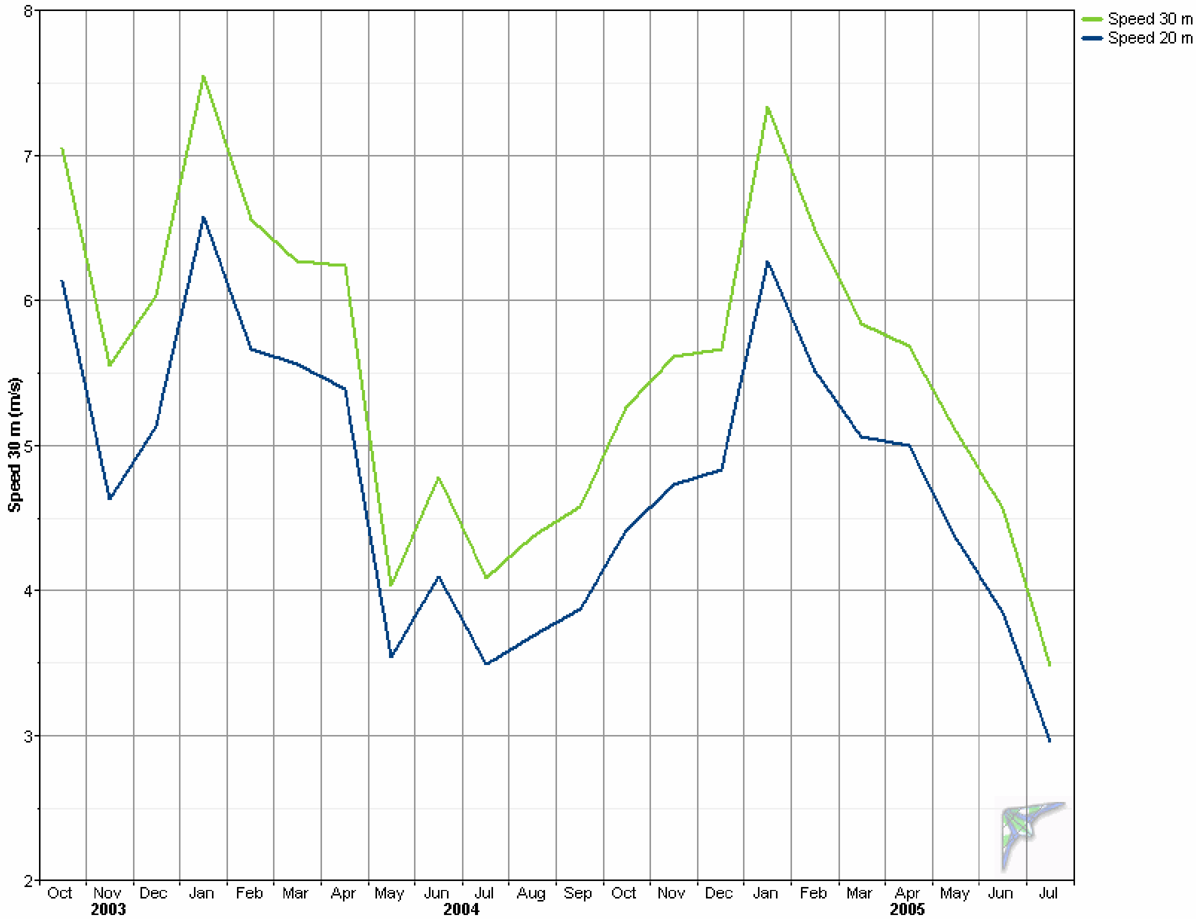
The daily wind profile indicates that the lowest wind speeds of the day occur in the morning hours of 3 to 6 a.m. and the highest wind speeds of the day occur during the afternoon and evening hours of 1 to 6 p.m. The daily variation of wind speed is minimal on an annual basis but more pronounced on a monthly basis.

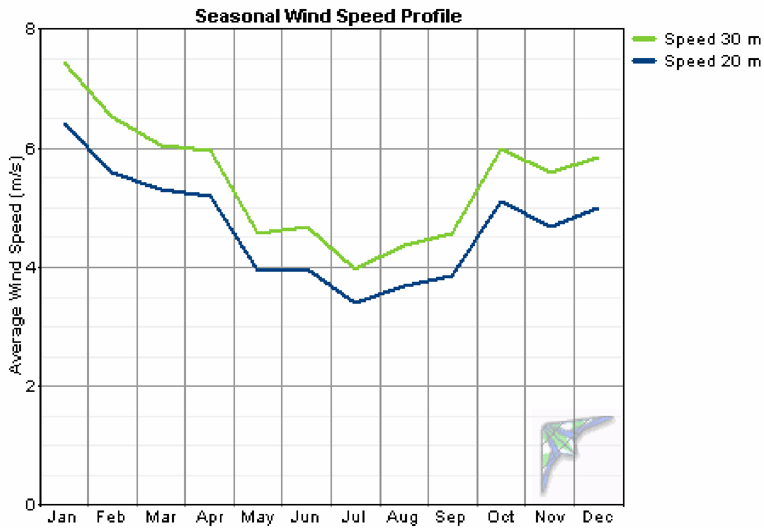




Time Series of Wind Speed Averages

As expected, higher winds occur during the winter and spring months of October through April while lower winds occur during the summer and autumn months, although the seasonal differential in New Stuyahok is more pronounced than observed in coastal villages.

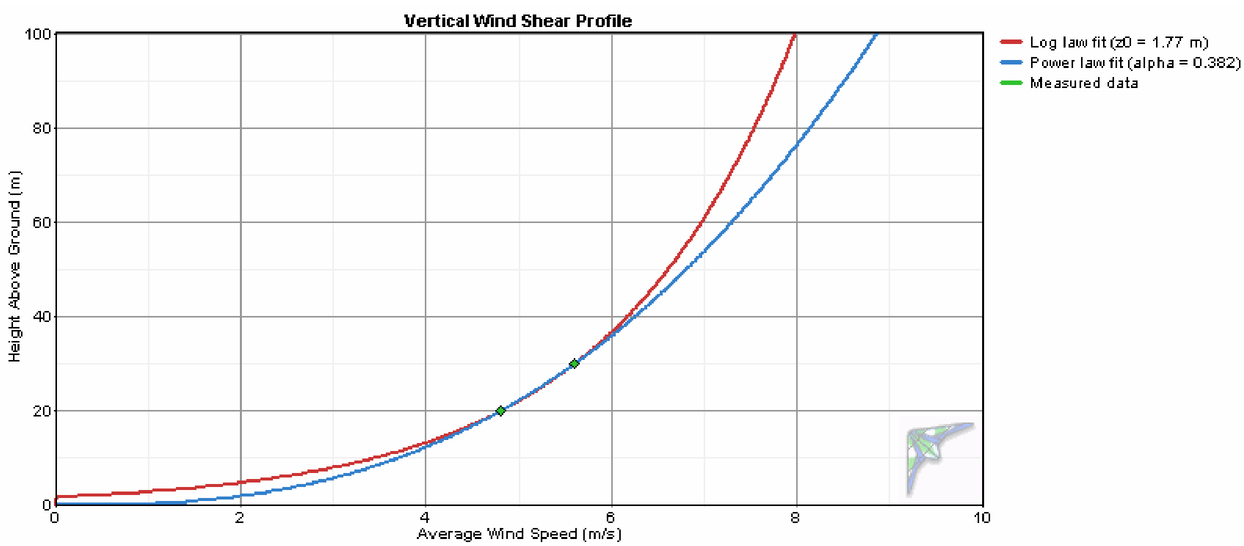


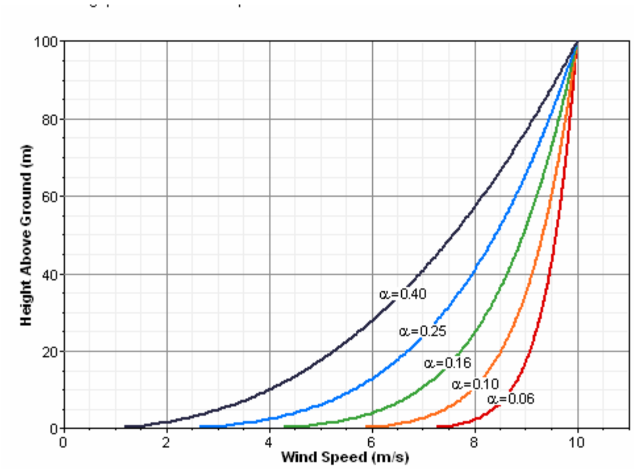


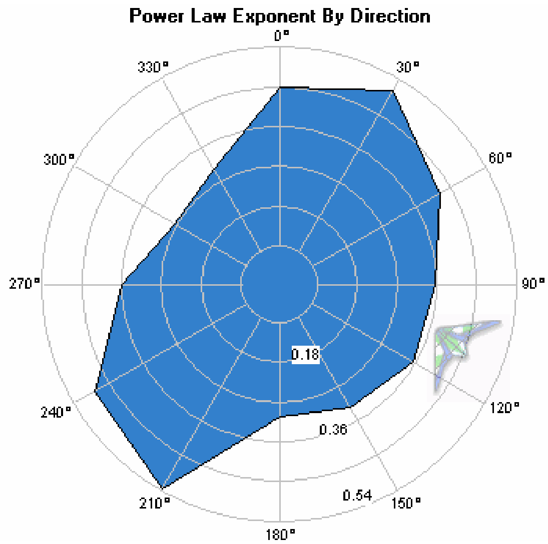
Wind Shear Profile

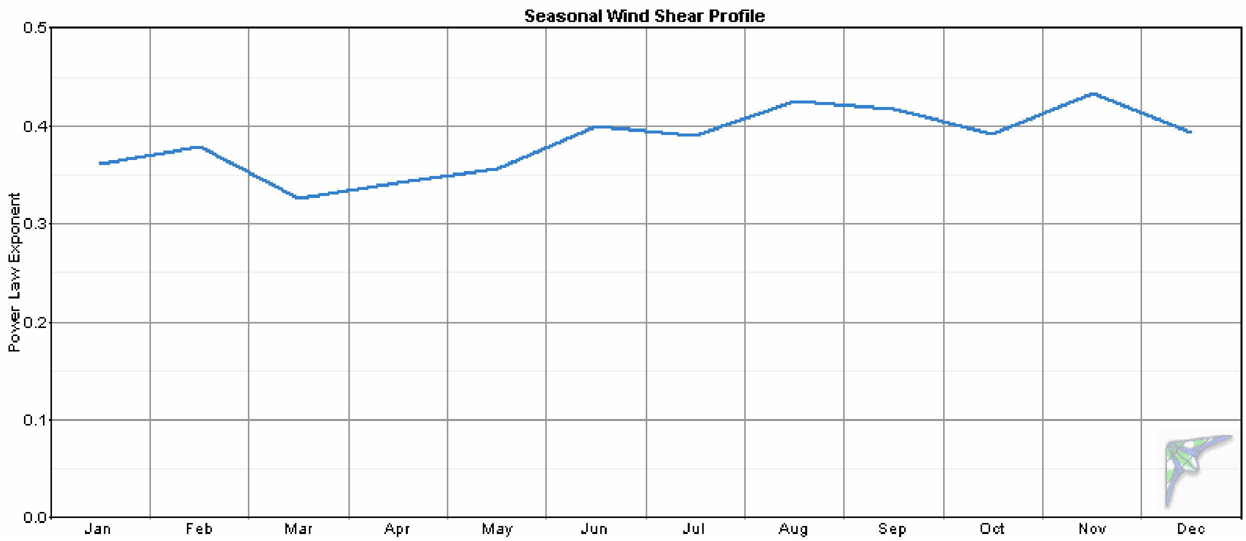
The power law exponent was calculated at 0.382, indicating high wind shear at the New Stuyahok test site, as noted in the second graph below. There is a possibility though that the presence of trees near the meteorological tower test site may have affected the 20 meter anemometer more significantly than the 30 m anemometer, resulting in a higher shear power law exponent than one might expect. In the village of Koliganek, upriver from New Stuyahok, a more open wind test site measured a wind shear of power law exponent of 0.227, which although moderately high itself, is more likely representative of New Stuyahok than the measured exponent of 0.382. If in fact the real shear exponent in New Stuyahok is lower than measured, the 50 meter wind power density listed in the data synopsis on page one of this report will be biased high and a 50 meter wind power density of approximately 375 to 400 W/m^2 is likely more realistic.

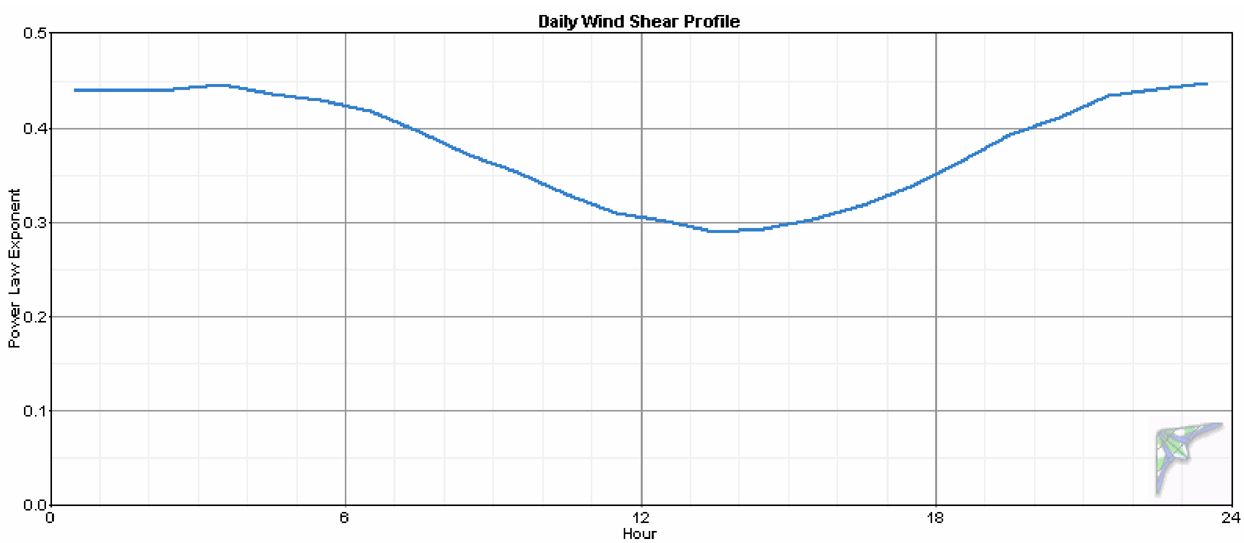
The practical application of this data is that a higher turbine tower height is desirable as there will be a substantial gain in wind speed/power recovery with additional height. A tower height/power recovery/ construction cost tradeoff study is advisable.





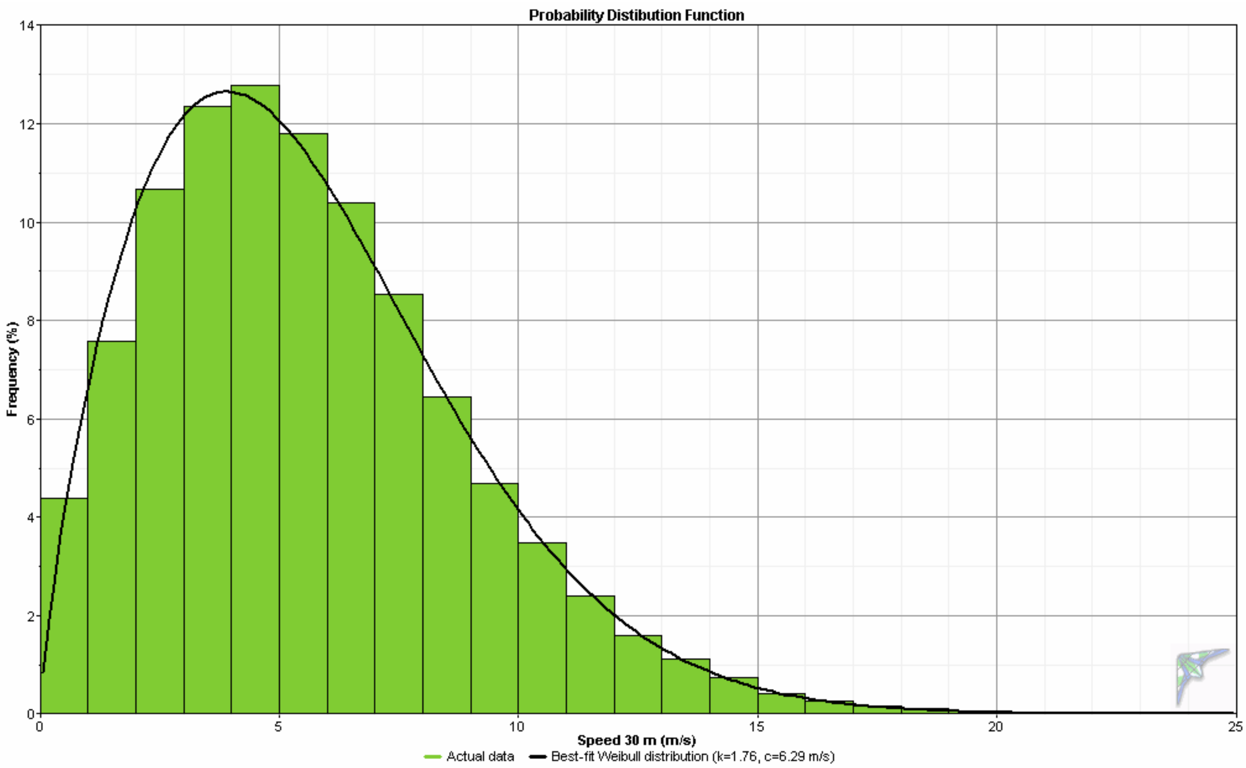

Power Law Exponent By Direction
0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
0.18
0.36
0.54

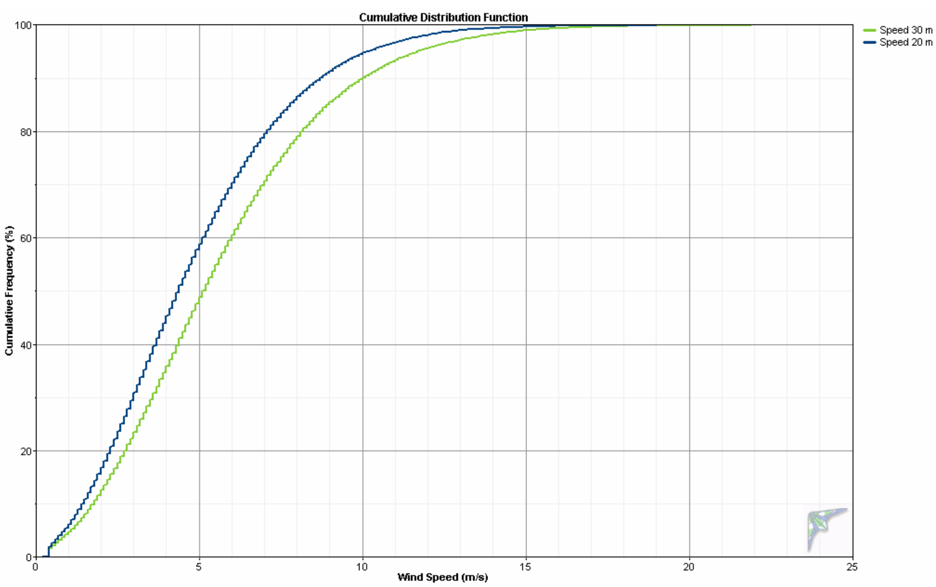

Seasonal Wind Shear Profile
Power Law Exponent
0.0
0.1
0.2
0.3
0.4
0.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Daily Wind Shear Profile
Power Law Exponent
0.0
0.1
0.2
0.3
0.4
0.5
0
6
12
18
24
Hour

Probability Distribution Function

The probability distribution function provides a visual indication of measured wind speeds in one meter per second "bins". Note that most wind turbines do not begin to generate power until the wind speed at hub height reaches 4 m/s. The black line in the graph is a best fit Weibull distribution. At the 30 meter level, measured Weibull parameters are k = 1.76 (indicates a moderate distribution of wind speeds) and c = 6.29 (scale factor). The PDF information is shown visually in another manner in the second graph, the Cumulative Distribution Function.



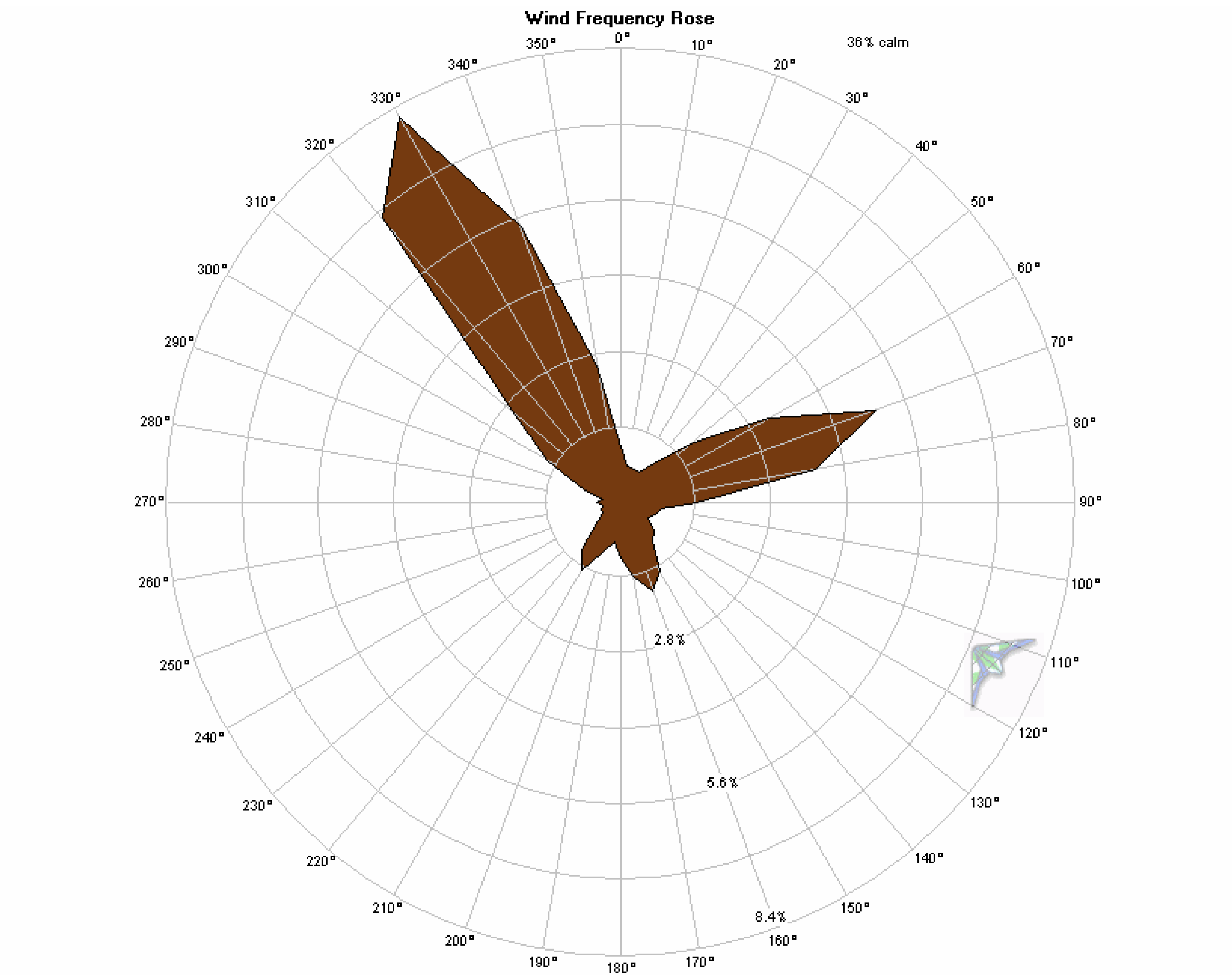


Wind Roses

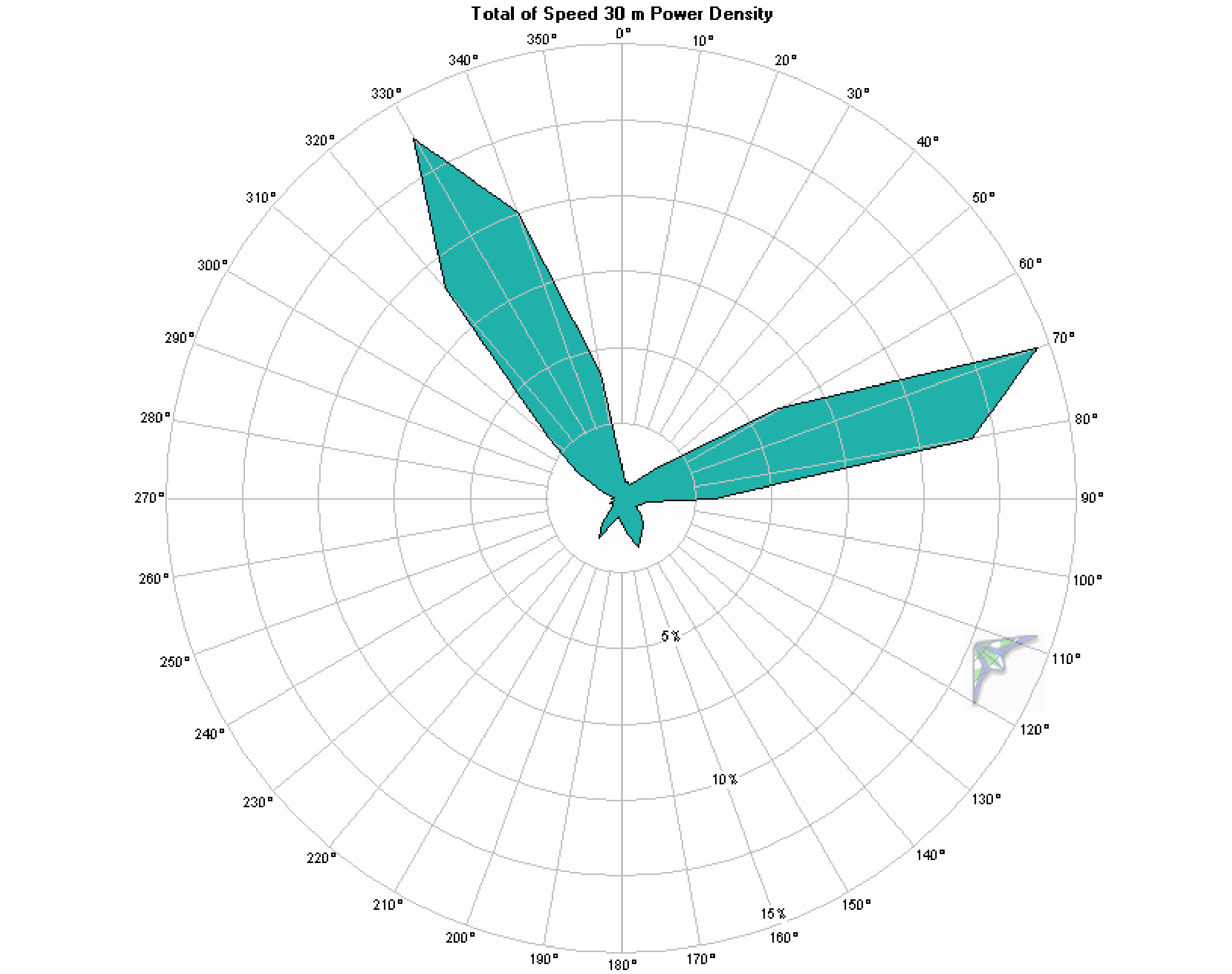
New Stuyahok winds are highly directional with, as the wind frequency rose indicates, north-northwest (NNW) and east-northeast (ENE) winds predominating. This observation is reinforced with reference to the power density rose below. The power producing winds in New Stuyahok are nearly exclusively NNW and ENE. The practical application of this information is that site(s) should be selected with relatively few obstructions from west to north to southeast to minimize wind turbulence at the turbines.

Note also that a wind threshold of 4 m/s was selected for the definition of calm winds. This wind speed represents the cut-in wind speed of most wind turbines. By this definition, Naknek experienced 36 percent calm conditions during the measurement period (see wind frequency rose below).

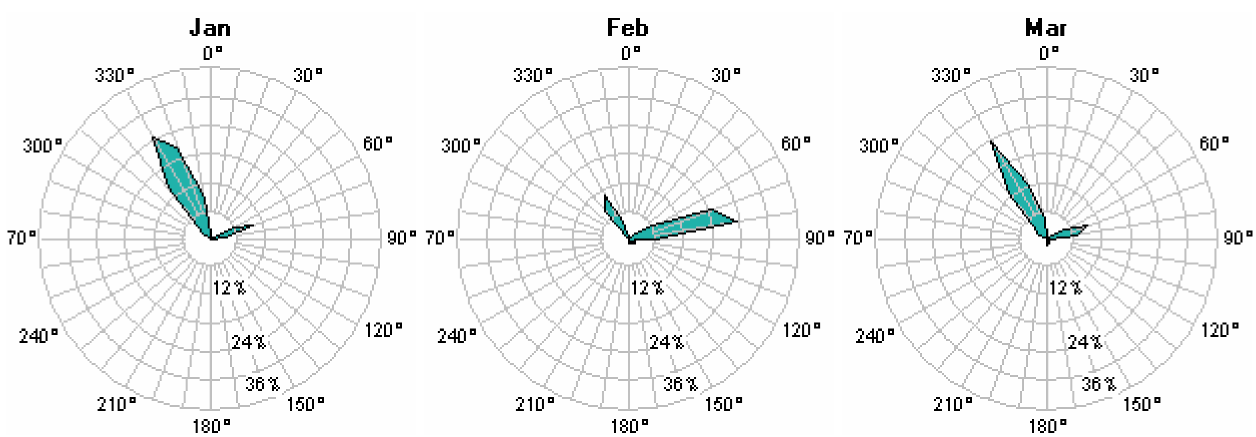
Wind Frequency Rose (30 meters)

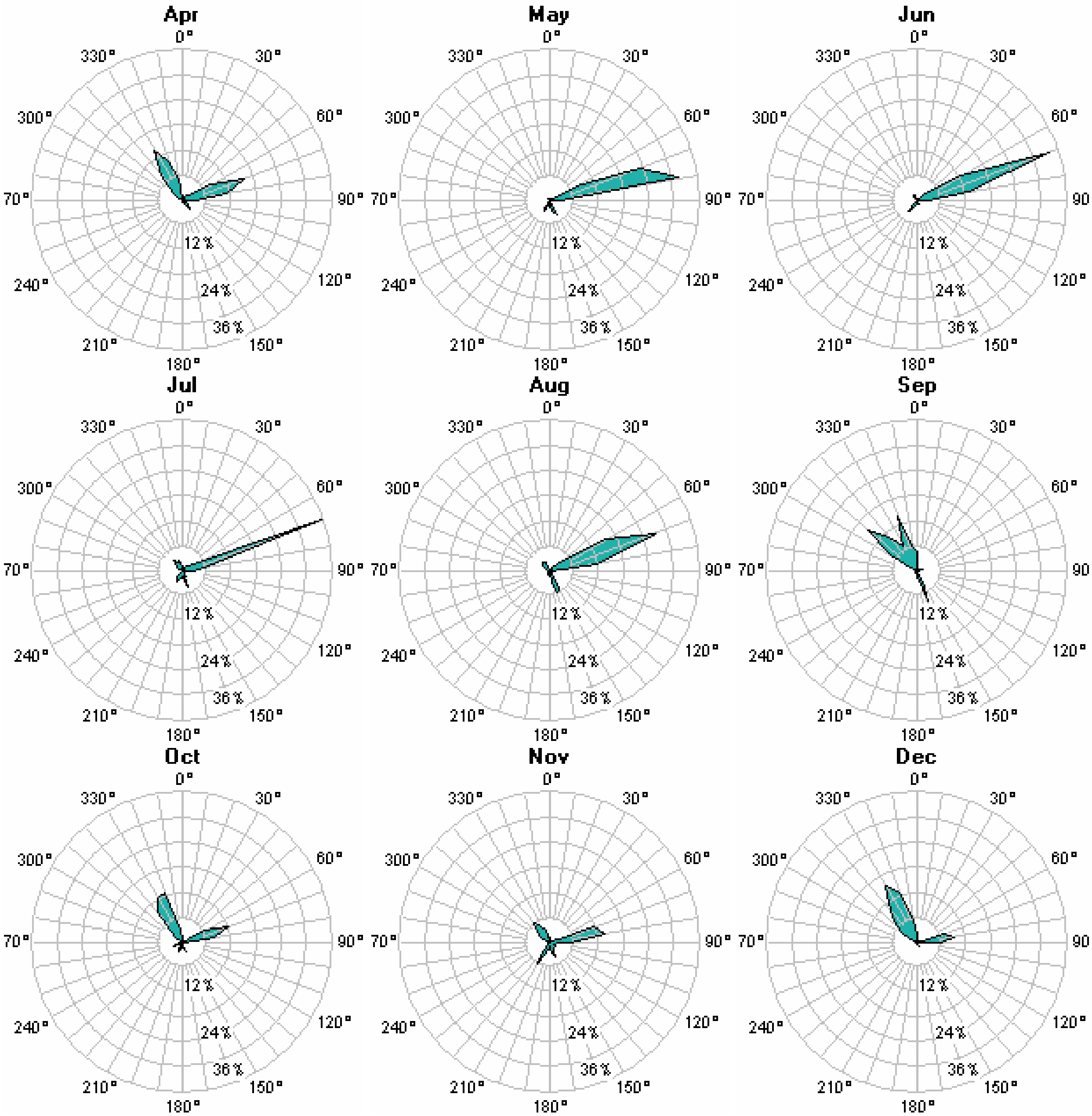


Wind Power Density Rose



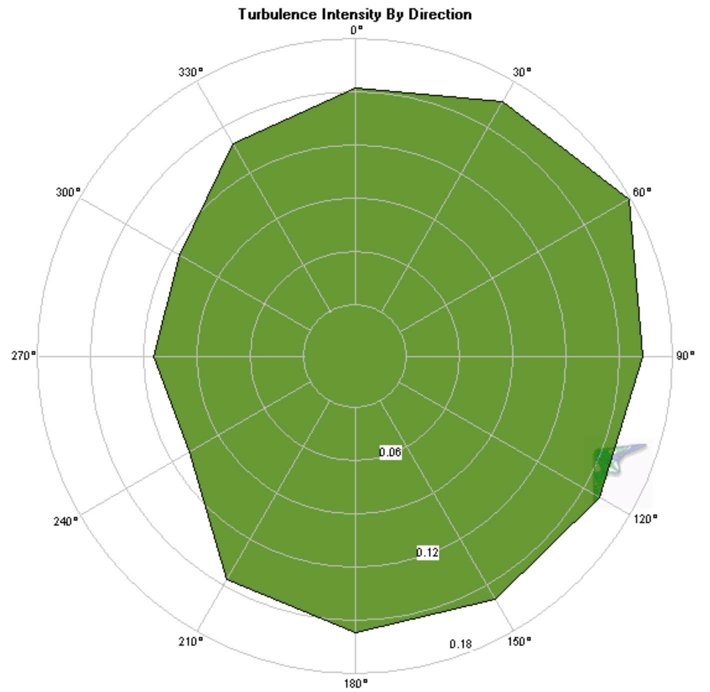
Wind Power Density Roses by Month




Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0°
30°
60°
90°
120°
150°
180°
210°
240°
70°
300°
330°
12%
24%
36%

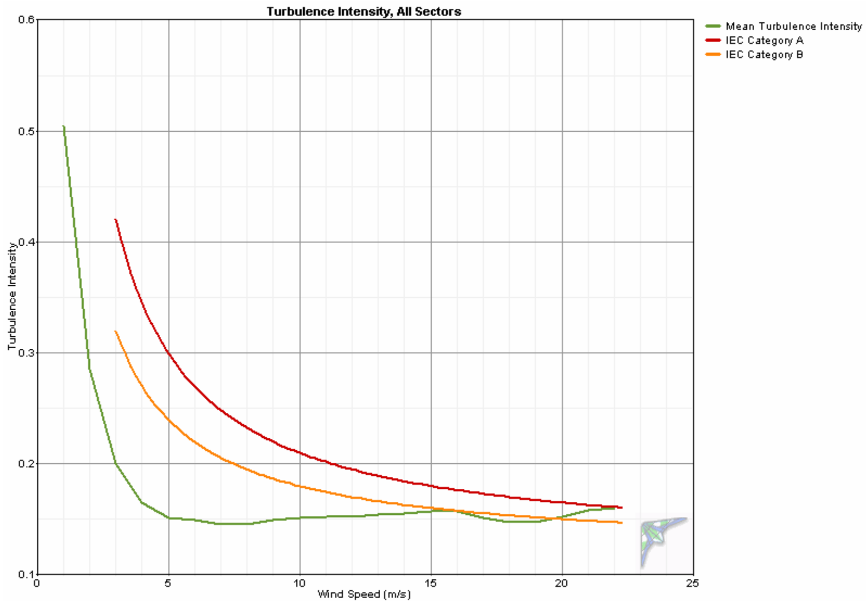
Turbulence Intensity

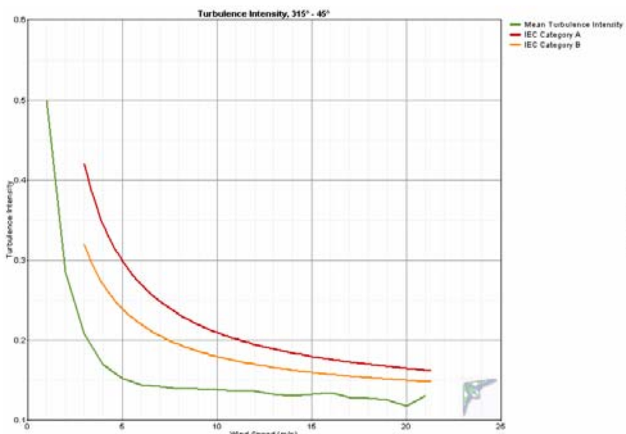
The turbulence intensity (TI) is minimally acceptable for all wind directions, with a mean turbulence intensity during the twenty-one month reporting period of 0.150 at 30 meters (threshold wind speed is 4 m/s).

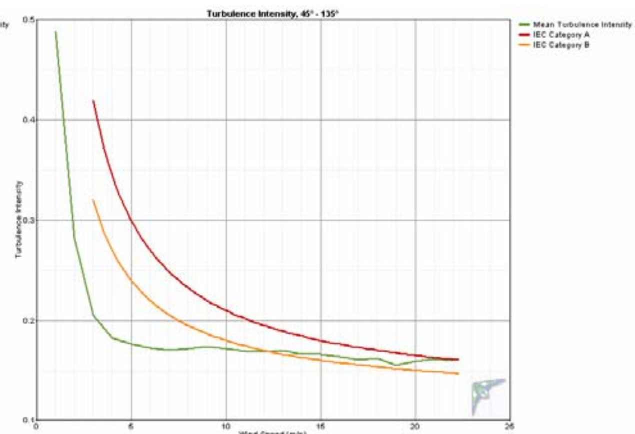


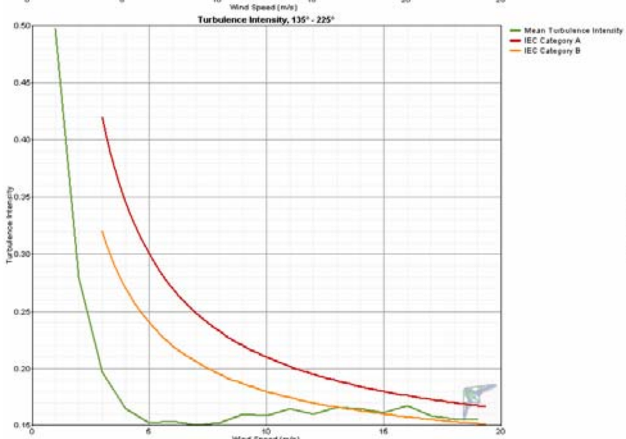
IEC Turbulence Intensity Standards

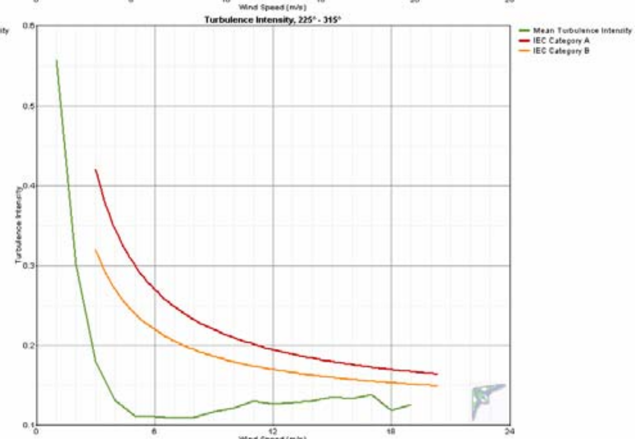
The turbulence intensities at 30 meters at the New Stuyahok project test site do not meet International Electrotechnical Commission (IEC) Category A standards in the northeast to southeast quadrant and IEC Category A in the southeast to southwest quadrant. This is less important in the SE to SW quadrant as the wind rarely blows from this direction, but is more so important in the NE to SE quadrant as significant power producing winds blow from the NE at this site.


Turbulence Intensity, All Sectors
Mean Turbulence Intensity
IEC Category A
IEC Category B
Turbulence Intensity
Wind Speed (m/s)


Turbulence Intensity, 315° - 45°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Wind Speed (m/s)


Turbulence Intensity, 45° - 135°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Wind Speed (m/s)


Turbulence Intensity, 135° - 225°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Wind Speed (m/s)


Turbulence Intensity, 225° - 315°
Mean Turbulence Intensity
IEC Category A
IEC Category B
Wind Speed (m/s)

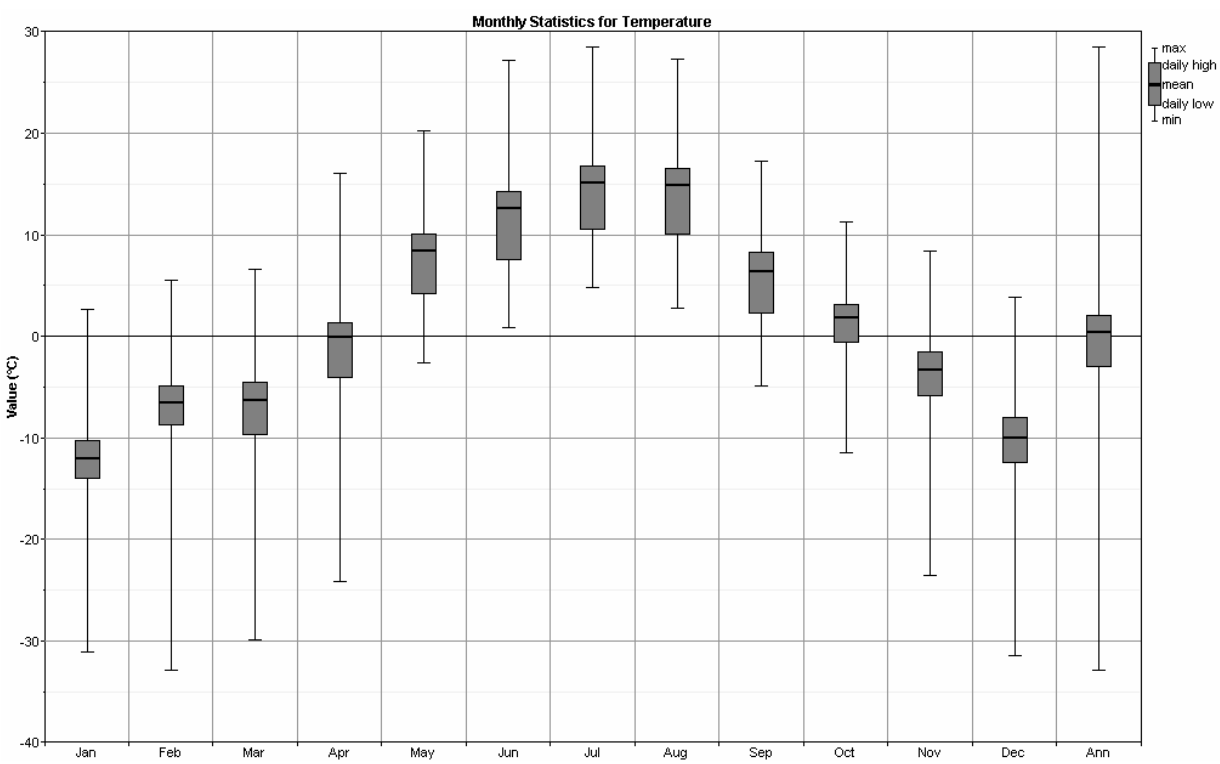
Turbulence Table

Bin Midpoint (m/s)	Bin Endpoints Lower (m/s)	Bin Endpoints Upper (m/s)	Records In Bin	Standard Deviation of Wind Speed (m/s)	Mean Turbulence Intensity	Standard Deviation of Turbulence Intensity	Characteristic Turbulence Intensity
1	0.5	1.5	5336	0.477	0.505	0.300	0.805
2	1.5	2.5	8533	0.556	0.285	0.149	0.434
3	2.5	3.5	10788	0.591	0.200	0.092	0.292
4	3.5	4.5	11573	0.654	0.165	0.069	0.235
5	4.5	5.5	11508	0.750	0.152	0.057	0.208
6	5.5	6.5	10122	0.887	0.149	0.048	0.197
7	6.5	7.5	8555	1.012	0.146	0.042	0.188
8	7.5	8.5	6830	1.153	0.145	0.040	0.185
9	8.5	9.5	5137	1.335	0.150	0.037	0.186
10	9.5	10.5	3683	1.501	0.151	0.033	0.184
11	10.5	11.5	2697	1.668	0.153	0.030	0.183
12	11.5	12.5	1783	1.818	0.153	0.030	0.182
13	12.5	13.5	1241	1.996	0.154	0.032	0.186
14	13.5	14.5	835	2.159	0.155	0.028	0.183
15	14.5	15.5	517	2.342	0.157	0.026	0.183
16	15.5	16.5	285	2.500	0.157	0.022	0.179
17	16.5	17.5	192	2.562	0.151	0.023	0.174
18	17.5	18.5	129	2.652	0.148	0.024	0.172
19	18.5	19.5	64	2.795	0.148	0.020	0.168
20	19.5	20.5	35	3.014	0.152	0.019	0.171
21	20.5	21.5	17	3.306	0.158	0.021	0.179
22	21.5	22.5	6	3.483	0.160	0.016	0.177

Air Temperature and Density

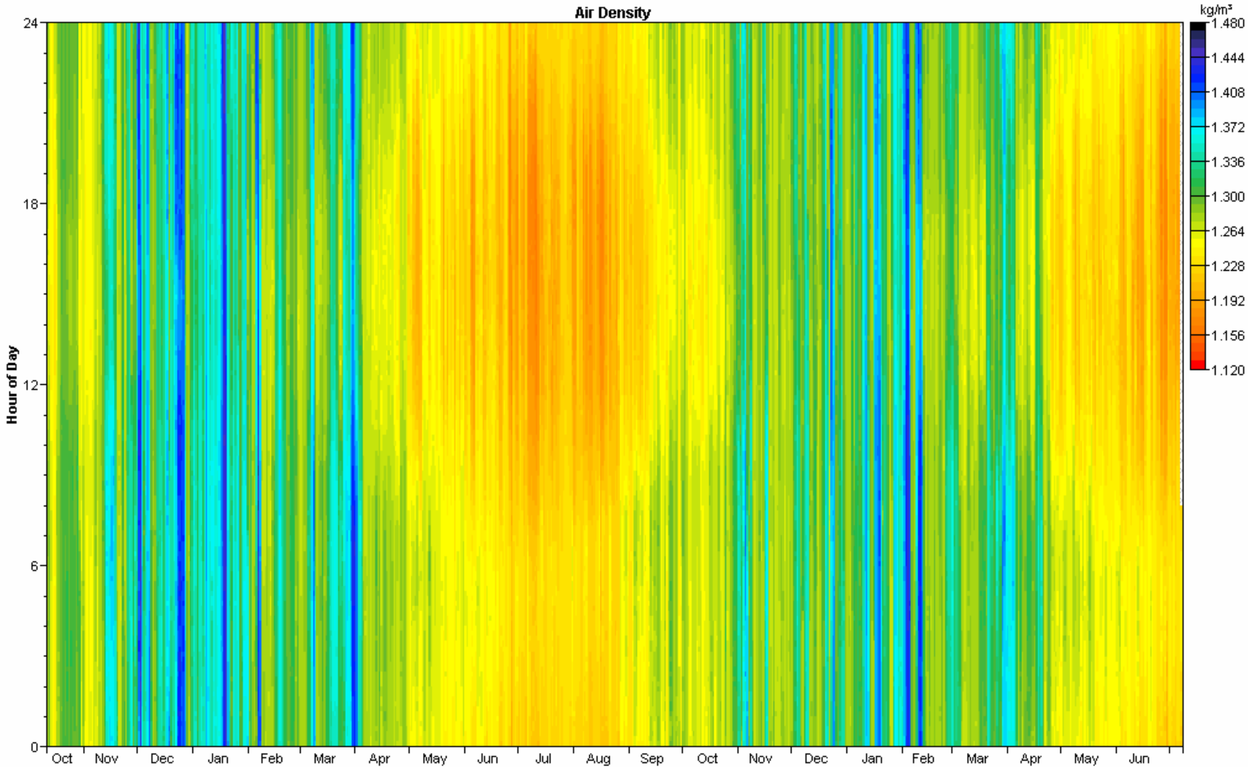
Over the reporting period, New Stuyahok had an average temperature of 1.7° C. The minimum recording temperature during the measurement period was -32.9° C and the maximum temperature was 28.5° C. Consequent to New Stuyahok's cool temperatures, the average air density of 1.275 kg/m^3 is approximately five percent higher than the standard air density of 1.217 kg/m^3 (at 14.5° C temperature and 100.46 kPa pressure at 70 m elevation).

	Temperature				Air Density		
Month	Mean (°C)	Min (°C)	Max (°C)	Std. Dev. (°C)	Mean (kg/m³)	Min (kg/m³)	Max (kg/m³)
Jan	-12.0	-31.1	2.7	7.37	1.341	1.269	1.446
Feb	-6.5	-32.9	5.5	9.02	1.314	1.256	1.457
Mar	-6.3	-29.9	6.6	7.72	1.313	1.251	1.439
Apr	-0.1	-24.1	16.0	6.93	1.283	1.210	1.405
May	8.5	-2.6	20.2	3.86	1.243	1.193	1.294
Jun	12.6	0.9	27.2	4.70	1.225	1.165	1.277
Jul	15.1	4.8	28.5	4.26	1.214	1.160	1.259
Aug	14.8	2.8	27.3	4.50	1.216	1.165	1.268
Sep	6.3	-4.9	17.2	4.57	1.253	1.205	1.305
Oct	1.8	-11.5	11.3	4.43	1.273	1.230	1.338
Nov	-3.3	-23.5	8.4	7.24	1.298	1.243	1.402
Dec	-10.0	-31.5	3.9	8.32	1.331	1.263	1.448
All data	**1.7**	-32.9	28.5	11.11	**1.275**	1.160	1.457



Air Density DMap

The DMap below is a visual indication of the daily and seasonal variations of air density (and temperature). Air densities higher than standard will yield higher turbine power than predicted by the turbine power curves, while densities lower than average will yield lower turbine power than predicted. Density variance from standard is accounted for in the turbine performance predictions.



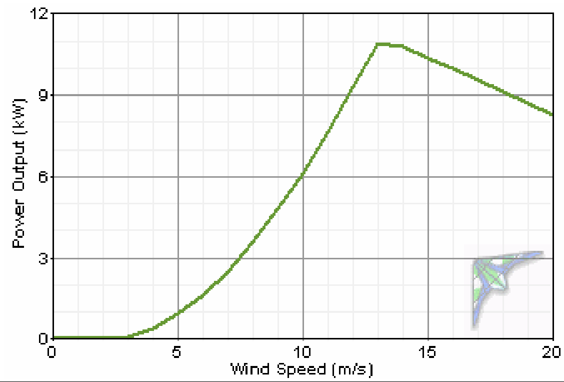
Wind Turbine Performance

The turbine performance predictions noted below are based on 100% and 90% turbine availabilities. It is realistic to expect five to ten percent downtime for maintenance, repairs and/or other outages should be expected.

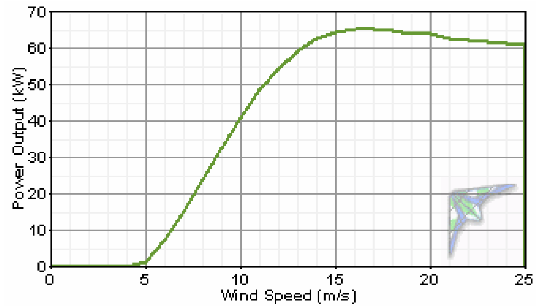
Note that these performance estimates were predicted with use of Windographer® wind analysis software; power curves provided by manufacturers are not independently verified and are assumed to be accurate. The power curves are presented for a standard air density of 1.225 kg/m^3 at 15° C temperature and 101.3 kPa at sea level; however the predictions of power production are density compensated by multiplying the standard density power output by the ratio of the measured air density to standard air density.

A number of smaller village-scale grid-connected turbines are profiled belong for comparison purposes. These turbines were selected because they have market availability and they are deemed to be within a suitable range for consideration of wind power development in a village the size of New Stuyahok.

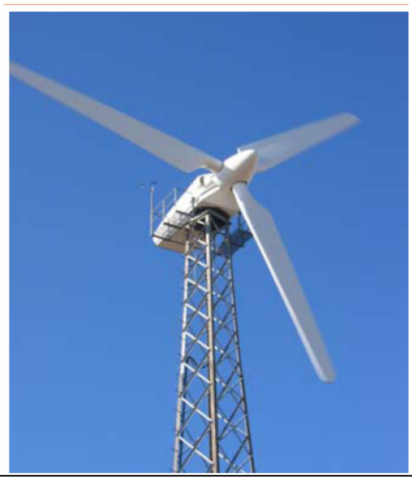
Bergey Excel-S: 10 kW rated power output, 6.7 meter rotor diameter, stall-controlled (power curve provided by Bergey). Available tower heights: 18, 24, 30, 37 and 43 meters. Additional information is available at www.bergey.com.

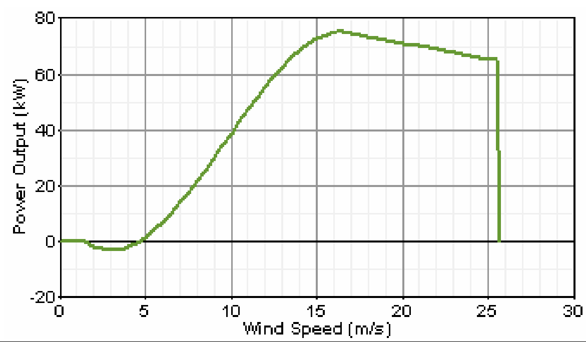


Entegrity eW-15: 65 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Entegrity Energy Systems). Available tower heights: 25 and 31 meters. Additional information is available at http://www.entegritywind.com/.

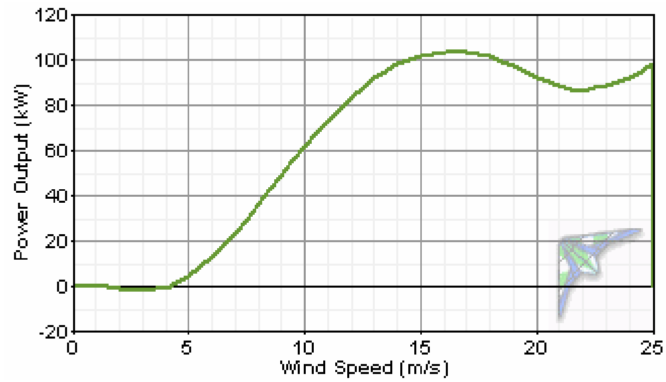


Vestas V15: 75 kW rated power output, 15 meter rotor, stall-controlled (power curve provided by Powercorp Alaska LLC). Available tower heights: 25, 31 and 34 meters. Additional information is available at http://www.pcorpalaska.com/.

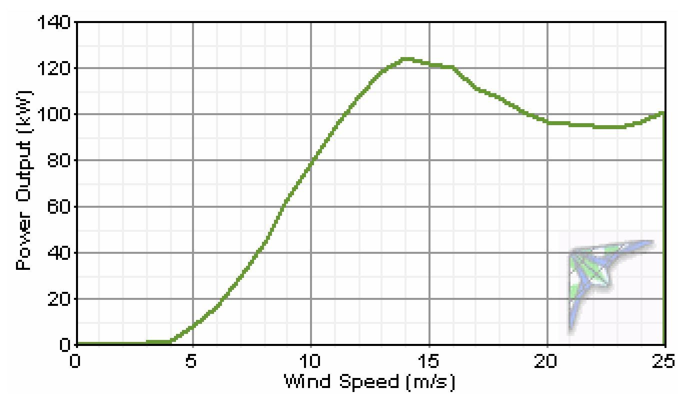




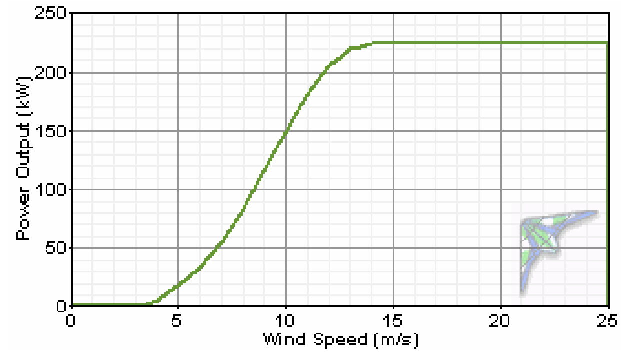
Northwind 100/19 and 100/20: 100 kW rated power output, 19 meter rotor and 20 meter rotor (19 meter rotor blades with 0.6 meter blade root extensions added) models, stall-controlled (power curve provided by Northern Power Systems). Available tower heights: 25 and 32 meters. Additional information is available at http://www.northernpower.com/.



Fuhrländer FL100: 100 kW rated output (125 kW max output), 21 meter rotor, stall-controlled, 35 meter hub height (power curve provided by lorax-energy.com). Available tower height: 35 meters. Additional information is available at http://www.lorax-energy.com/.



Vestas V27: 225 kW rated power output, 27 meter rotor, pitch-controlled (power curve provided by Alaska Energy Authority)


Power Output (kW)
250
200
150
100
50
0
0
5
10
15
20
25
Wind Speed (m/s)

Turbine Power Output Comparison (100% availability)

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Bergey Excel-S	37	5.90	12.08	4.22	2.47	21,566	24.7
Entegrity eW-15 60 Hz	31	5.51	36.74	1.98	12.65	110,550	19.5
Vestas V15	34	5.71	42.09	1.47	12.57	109,652	16.7
Northern Power NW 100/20	32	5.57	36.05	1.92	19.11	167,109	19.1
Fuhrländer FL100	35	5.77	12.55	2.42	28.29	247,355	22.6
Vestas V27	42	6.19	15.60	2.51	60.49	529,059	26.9

Capacity Factor <20%
Capacity Factor >20%, <30%
Capacity Factor >30%, <40%
Capacity Factor >40%, <50%
Capacity Factor >50%

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	0
Array (%)	0
Icing/soiling (%)	0
Other (%)	0
Total (%)	0

Turbine Power Output Comparison (90% availability)

Turbine	Hub Height (m)	Hub Height Wind Speed (m/s)	Time At Zero Output (%)	Time At Rated Output (%)	Average Net Power Output (kW)	Annual Net Energy Output (kWh/yr)	Average Net Capacity Factor (%)
Bergey Excel-S	37	6.04	11.6	4.6	2.3	19,476	22.3
Entegrity eW-15 60 Hz	31	5.65	35.1	2.3	12.1	99,838	17.6
Vestas V15	34	5.85	40.3	1.7	12.1	99,027	15.1
Northern Power NW 100/20	32	5.72	34.5	2.2	18.3	150,916	17.3
Fuhrländer FL100	35	5.92	12.1	2.8	27.0	223,386	20.4
Vestas V27	42	6.35	14.9	2.8	57.5	477,793	24.3

Capacity Factor <20%	(orange)
Capacity Factor >20%, <30%	(yellow)
Capacity Factor >30%, <40%	(green)
Capacity Factor >40%, <50%	(cyan)
Capacity Factor >50%	(light blue)

Assumed turbine losses for predictions of average power output, annual energy output, and average capacity factor:

Downtime (%)	5	
Array (%)	0	
Icing/soiling (%)	3	
Other (%)	2	
Total (%)	9.69	(factors are multiplicative)

Annual Fuel Cost Avoided for Energy Generated by Wind Turbine vs. Diesel Generator

Turbine	Annual Energy Output (kW-hr/yr)	Fuel Quantity Avoided (gallons)	Fuel Price (USD/gallon)							Turbine Hub Height (m)
			$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	
Bergey Excel-S	20,522	1,642	$2,873	$3,284	$3,694	$4,104	$4,515	$4,925	$5,336	37
Entegrity eW-15 60 Hz	106,345	8,508	$14,888	$17,015	$19,142	$21,269	$23,396	$25,523	$27,650	31
Vestas V15	106,145	8,492	$14,860	$16,983	$19,106	$21,229	$23,352	$25,475	$27,598	34
Northern Power NW 100/20	160,595	12,848	$22,483	$25,695	$28,907	$32,119	$35,331	$38,543	$41,755	32
Fuhrländer FL100	236,560	18,925	$33,118	$37,850	$42,581	$47,312	$52,043	$56,774	$61,506	35
Vestas V27	503,500	40,280	$70,490	$80,560	$90,630	$100,700	$110,770	$120,840	$130,910	42

Notes:
1. New Stuyahok electrical energy production efficiency assumed to be 12.5 kW-hr/gal
2. Assumes <u>90%</u> wind turbine availability with no diversion of power to a thermal or other dump load
3. Assumes linear diesel generator fuel efficiency (i.e., 1:1 tradeoff of wind turbine kW-hr to diesel genset kW-hr)

Temperature Conversion Chart °C to °F

°C	°F	°C	°F	°C	°F
-40	-40.0	-10	14.0	20	68.0
-39	-38.2	-9	15.8	21	69.8
-38	-36.4	-8	17.6	22	71.6
-37	-34.6	-7	19.4	23	73.4
-36	-32.8	-6	21.2	24	75.2
-35	-31.0	-5	23.0	25	77.0
-34	29.2	-4	24.8	26	78.8
-33	-27.4	-3	26.6	27	80.6
-32	-25.6	-2	28.4	28	82.4
-31	-23.8	-1	30.2	29	84.2
-30	-22.0	0	32.0	30	86.0
-29	-20.2	1	33.8	31	87.8
-28	-18.4	2	35.6	32	89.6
-27	-16.6	3	37.4	33	91.4
-26	-14.8	4	39.2	34	93.2
-25	-13.0	5	41.0	35	95.0
-24	-11.2	6	42.8	36	96.8
-23	-9.4	7	44.6	37	98.6
-22	-7.6	8	46.4	38	100.4
-21	-5.8	9	48.2	39	102.2
-20	-4.0	10	50.0	40	104.0
-19	-2.2	11	51.8	41	105.8
-18	-0.4	12	53.6	42	107.6
-17	1.4	13	55.4	43	109.4
-16	3.2	14	57.2	44	111.2
-15	5.0	15	59.0	45	113.0
-14	6.8	16	60.8	46	114.8
-13	8.6	17	62.6	47	116.6
-12	10.4	18	64.4	48	118.4
-11	12.2	19	66.2	49	120.2

Wind Speed Conversion Chart, m/s to mph

m/s	mph	m/s	mph	m/s	mph	m/s	mph	m/s	mph
0.5	1.1	10.5	23.5	20.5	45.9	30.5	68.2	40.5	90.6
1.0	2.2	11.0	24.6	21.0	47.0	31.0	69.3	41.0	91.7
1.5	3.4	11.5	25.7	21.5	48.1	31.5	70.5	41.5	92.8
2.0	4.5	12.0	26.8	22.0	49.2	32.0	71.6	42.0	93.9
2.5	5.6	12.5	28.0	22.5	50.3	32.5	72.7	42.5	95.1
3.0	6.7	13.0	29.1	23.0	51.4	33.0	73.8	43.0	96.2
3.5	7.8	13.5	30.2	23.5	52.6	33.5	74.9	43.5	97.3
4.0	8.9	14.0	31.3	24.0	53.7	34.0	76.1	44.0	98.4
4.5	10.1	14.5	32.4	24.5	54.8	34.5	77.2	44.5	99.5
5.0	11.2	15.0	33.6	25.0	55.9	35.0	78.3	45.0	100.7
5.5	12.3	15.5	34.7	25.5	57.0	35.5	79.4	45.5	101.8
6.0	13.4	16.0	35.8	26.0	58.2	36.0	80.5	46.0	102.9
6.5	14.5	16.5	36.9	26.5	59.3	36.5	81.6	46.5	104.0
7.0	15.7	17.0	38.0	27.0	60.4	37.0	82.8	47.0	105.1
7.5	16.8	17.5	39.1	27.5	61.5	37.5	83.9	47.5	106.3
8.0	17.9	18.0	40.3	28.0	62.6	38.0	85.0	48.0	107.4
8.5	19.0	18.5	41.4	28.5	63.8	38.5	86.1	48.5	108.5
9.0	20.1	19.0	42.5	29.0	64.9	39.0	87.2	49.0	109.6
9.5	21.3	19.5	43.6	29.5	66.0	39.5	88.4	49.5	110.7
10.0	22.4	20.0	44.7	30.0	67.1	40.0	89.5	50.0	111.8

Distance Conversion m to ft

m	ft	m	ft
5	16	35	115
10	33	40	131
15	49	45	148
20	66	50	164
25	82	55	180
30	98	60	197

Selected definitions (courtesy of Windographer® software by Mistaya Engineering Inc.)

Wind Power Class

The wind power class is a number indicating the average energy content of the wind resource. Wind power classes are based on the average wind power density at 50 meters above ground, according to the following table. Source: Wind Energy Resource Atlas of the United States (http://rredc.nrel.gov/wind/pubs/atlas/tables/A-8T.html)

Wind Power Class	Description	Power Density at 50m (W/m^2)
1	Poor	0-200
2	Marginal	200-300
3	Fair	300-400
4	Good	400-500
5	Excellent	500-600
6	Outstanding	600-800
7	Superb	800-2000

Windographer classifies any wind resource with an average wind power density above 2000 W/m^2 as class 8.

Probability Distribution Function

The probability distribution function f(x) gives the probability that a variable will take on the value x. It is often expressed using a frequency histogram, which gives the frequency with which the variable falls within certain ranges or bins.

Wind Turbine Power Regulation

All wind turbines employ some method of limiting power output at high wind speeds to avoid damage to mechanical or electrical subsystems. Most wind turbines employ either stall control or pitch control to regulate power output.

A stall-controlled turbine typically has blades that are fixed in place, and are designed to experience aerodynamic stall at very high wind speeds. Aerodynamic stall dramatically reduces the torque produced by the blades, and therefore the power produced by the turbine.

On a pitch-controlled turbine, a controller adjusts the angle (pitch) of the blades to best match the wind speed. At very high wind speeds the controller increasingly feathers the blades out of the wind to limit the power output.